

**MINERALOGY AND ELEMENTAL COMPOSITION OF WIND DRIFT SOIL AT ROCKNEST, GALE CRATER.** D.F. Blake<sup>1</sup>, D.L. Bish<sup>2</sup>, R.V. Morris<sup>3</sup>, R.T. Downs<sup>4</sup>, A.H. Treiman<sup>5</sup>, S.M. Morrison<sup>4</sup>, S.J. Chipera<sup>6</sup>, D.W. Ming<sup>3</sup>, A.S. Yen<sup>7</sup>, D.T. Vaniman<sup>8</sup>, J. Grotzinger<sup>9</sup>, J.A. Crisp<sup>7</sup>, C.N. Achilles<sup>10</sup>, E.B. Rampe<sup>3</sup>, T.F. Bristow<sup>1</sup>, P.C. Sarrazin<sup>11</sup>, J.D. Farmer<sup>12</sup>, D.J. Des Marais<sup>1</sup>, E.M. Stolper<sup>9</sup>, J.M. Morookian<sup>7</sup>, M.A. Wilson<sup>1</sup>, N. Spanovich<sup>7</sup>, R.C. Anderson<sup>7</sup> and the MSL Science Team. <sup>1</sup>NASA Ames Research Center ([david.blake@nasa.gov](mailto:david.blake@nasa.gov)), <sup>2</sup>Indiana Univ., <sup>3</sup>NASA Johnson Space Center, <sup>4</sup>Univ. of Arizona, <sup>5</sup>LPI, <sup>6</sup>CHK Energy, <sup>7</sup>Jet Propulsion Lab., <sup>8</sup>PSI, <sup>9</sup>Cal Tech., <sup>10</sup>ES&C/Hamilton Sundstrand, <sup>11</sup>in Xitu, Inc., <sup>12</sup>Arizona State Univ.

**Introduction:** The Mars Science Laboratory rover *Curiosity* has been exploring Mars since August 5, 2012, conducting engineering and first-time activities with its mobility system, arm, sample acquisition and processing system (SA/SPaH–CHIMRA) and science instruments. *Curiosity* spent 54 sols at a location named “Rocknest,” collecting and processing five scoops of loose, unconsolidated materials (“soil”) acquired from an aeolian bedform (Fig. 1). The Chemistry and Mineralogy (CheMin) instrument analyzed portions of scoops 3, 4, and 5, to obtain the first quantitative mineralogical analysis of Mars soil, and to provide context for Sample Analysis at Mars (SAM) measurements of volatiles, isotopes and possible organic materials.

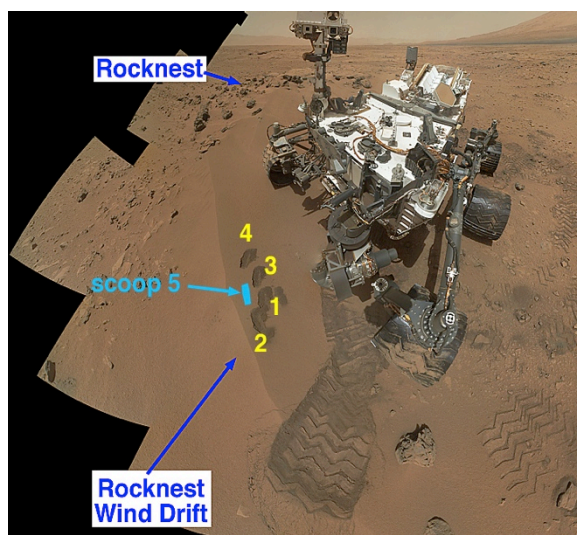


Fig. 1. MAHLI image, showing the location of scoops 1-5 in the Rocknest wind drift.

**Description of the Rocknest aeolian bedform:** The aeolian bedform at Rocknest is strikingly similar to other coarse-grained ripples encountered at Gusev by *Spirit* [1]. A surface layer of larger grains (~1-2 mm) armors finer-grained subsurface material [2]. There is sub-cm scale color banding beneath the surface (Fig. 2), suggestive of changes in composition, local variation in mean particle diameter, or oxidation state. Scooped soil from the drift moved freely when the scoop was vibrated, indicating that the material is

dry and powdery. MAHLI images of <150  $\mu\text{m}$ -sized grains deposited on *Curiosity*'s observation tray show a variety of particle types from clear to colored to dark, angular to spherical, dull to glassy, suggesting a wide variety of individual mineral and glass fragments [3].

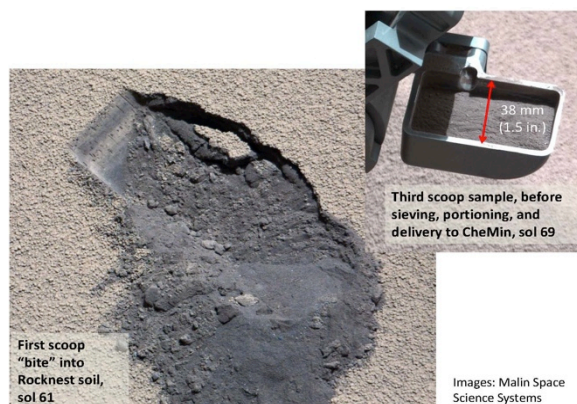


Fig. 2. MastCam image of scoop mark in the Rocknest wind drift and (inset) soil from scoop 3.

**Mineralogy & Elemental Composition of Rocknest Soil:** Scoops 3, 4, and 5 were individually sieved to <150  $\mu\text{m}$  and delivered to the CheMin XRD/XRF instrument. X-ray diffraction results are reported in [4].

Fig. 3 shows the XRD pattern obtained from scoop 5. These results are typical of all three scoops of material analyzed by CheMin. Rocknest soil consists of crystalline and X-ray amorphous material. The crystalline component is basaltic, comprised of plagioclase (~An50), forsteritic olivine (~Fo58), augite and

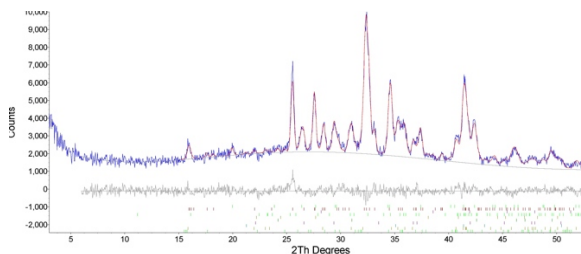


Fig. 3. XRD pattern and Rietveld refinement of Rocknest soil, scoop 5 [4]. Blue line = observed data, red line = Rietveld refinement best fit, gray line = residual between fitted and observed.

pigeonite. Minor phases include sanidine, magnetite, quartz, anhydrite, hematite and ilmenite. The inclusion of these minor phases improves the fit of the data refinement, but some are at CheMin's Minimum Detection Limit (MDL) of ~1-2 % by mass. Volatiles and volatile-bearing components inferred to be present from the SAM GC-MS experiment, including H<sub>2</sub>O, carbonates, perchlorates, and sulfates, must either be present in concentrations below this MDL, or be present in the X-ray amorphous component.

The poorly crystalline or XRD amorphous component is indicated for Rocknest soil by the broad hump centered at ~30° 2 $\theta$  and the increase in intensity at low 2 $\theta$ . To quantify the amount of amorphous material present in the soil, XRD patterns of many synthetic and natural poorly crystalline materials were collected in CheMin prototype instruments and their relative intensity ratios (RIR's) were determined [5,6]. The proportion of amorphous material in the Rocknest soil was then calculated using Fullpat [7]. The result indicates that ~27±15% of Rocknest soil scoop 5 is amorphous, having the diffraction characteristics of basaltic glass or palagonite with a minor component of allophane (although the specific identity of the amorphous material is unclear) [4]. This value, derived solely from X-ray scattering data (i.e., structure), compares favorably with a value of 36% derived solely from compositional and Mössbauer data [8].

For the crystalline component of the soil, elemental compositions were calculated from unit-cell parameters determined by Rietveld refinement. The composition of forsterite is well constrained by its refined unit cell, but those of the plagioclase and pyroxenes are less so, as they have a greater diversity of possible solid solutions. By constraining the compositions of the individual crystalline phases, the composition of the crystalline component of the Rocknest soil can be calculated [9]. Using this value and the overall composition determined by APXS, the proportion of amorphous components can be calculated. The result (37%) compares favorably with the proportion of amorphous components calculated from composition alone (36% [8]). The composition of the amorphous material can be obtained by subtracting the composition of the crystalline component from the bulk composition determined by APXS [1]. The values, obtained from structural data [9], agree with those obtained from compositional data [8] to within 1.7 wt. %.

#### **The Source(s) of Rocknest Soil:**

*Global, regional and local sources.* The mineralogy of the crystalline component of the Rocknest soil is basaltic and fits well within the measured *qualitative* mineralogy of basaltic Martian meteorites [10] and the

normative mineralogy of Adirondack class olivine basalts reported at Gusev [11]. If the basaltic crystalline component of Rocknest soil is indeed locally derived, it is interesting to note that it is identical within measurement error to olivine basalts measured at Gusev [10,11] and quite different from local basaltic composition float rocks measured by the APXS and ChemCam instruments on *Curiosity* [12]. Furthermore, there is no crystalline component within the Rocknest soil that reflects the mineralogy of the (nearby) lower strata of Mt. Sharp, which contain hydrated sulfates and phyllosilicates [13]. Transport mechanisms can be imagined for the fine-grained global component (perhaps represented by the ~30-40% amorphous fraction), but it is difficult to understand how the coarser-grained basaltic crystalline phases could have been transported for long distances, apparently unaltered.

*Ancient and recent sources of soil components at Rocknest?* It is possible that the amorphous component of Rocknest soil is geologically old and global in scope – a “last man standing” result of physical and chemical weathering – and the crystalline basaltic component is fresh, geologically recent and local. Mars is a basaltic planet, and it is not inconceivable that basalts in disparate locations on Mars would have similar compositions. APXS and Mössbauer measurements at Gusev crater [11,14] showed that some soils have local components derived from nearby rocks. Perhaps with continued measurements of soil in Gale crater as *Curiosity* treks toward Mount Sharp, sources of local, regional, and global components will be better constrained. The measurement of differing crystalline components mixed with the common global soil will allow us to tease out the composition and mineralogy of the global component.

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**References:** [1] Yen A.S. et al. (2013), *LPS XLIV*, Abstract. [2] Kocurek, G. et al. (2013), *LPS XLIV*, Abstract. [3] Edgett K.S. et al. (2013), *LPS XLIV*, Abstract. [4] Bish D.L. et al. (2013), *LPS XLIV*, Abstract. [5] Achilles C.N. et al. (2013), *LPS XLIV*, Abstract. [6] Rampe E.L. et al. (2013), *LPS XLIV*, Abstract. [7] Chipera, S.J. & Bish D.L. (2002), *J. App. Cryst.*, 35, 744-749; [8] Morris R.V. et al. (2013), *LPS XLIV*, Abstract. [9] Morrison S.M. et al. (2013), *LPS XLIV*, Abstract. [10] Treiman A.H. et al. (2013), *LPS XLIV*, Abstract. [11] Ming D.W. et al (2008), *JGR*, 113, E12S39; [12] Schmidt et al. (2013), *LPS XLIV*, Abstract. [13] Milliken R.E. et al. (2010), *GRL* 37, L040201; [14] Morris R.V. et al. (2008), *JGR* 113, E12842.